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PROBLEMS IN ATTEMPTING TO MEASURE $d\sigma/dt$ ($\gamma p \to \gamma p$) COMPTON SCATTERING

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These notes are some incompletely worked out ideas on this subject.

1. Is it worthwhile to measure $d\sigma/dt$ at $t = 0$?

If we assume σ_{TOT} ($\gamma p \to$hadrons) can be measured to ~ ±2%, and if we make a perfect measurement of $d\sigma/dt$ ($\gamma p \to \gamma p$) at $t = 0$, the most we can do is limit the size of the real part of the forward compton amplitude to 20% of the imaginary. According to my (imperfect) understanding of the physics, such a big real part is most unlikely in the 50 to 100 GeV region. So it does not seem worthwhile, except to look for big surprises.

The t-dependence of $d\sigma/dt$ is less "fundamental." Any big difference from the approximately exp(10t) dependence of the hadron diffraction scattering would be of interest, however. It is easier to measure, since we can turn the argument above backwards to say that the measurement of σ_{TOT} ($\gamma p \to$hadrons) gives us one point on the curve already, at $t = 0$.

2. Can a single-arm system which measures only the forward photon work?

Assuming 100 μbarns for σ_{TOT} and a t-dependence for the elastic scattering of exp(10t) we get a total elastic cross section of 1/20 μbarns.

This is only 1/2000 of the total ($\gamma p \rightarrow$hadrons) cross section. It is a much smaller fraction of the background of purely electromagnetic interactions. Backgrounds of the type

$$\gamma p \rightarrow \begin{matrix} \pi^0 p \\ \pi^0 N^* \\ \gamma \ N^* \end{matrix} \Big\} M(N^*) \lesssim 2 \text{ GeV}$$

will always give photons whose energy is within a percent or so of the energy of the incident photon at 100 GeV. Beam halo itself will be a severe problem. We do not have enough flux to collimate down to a minute pencil. Per gram of liquid hydrogen we have 3×10^{-8} elastic interactions per incident photon. I do not see how we can expect to approach this level in the beam halo by several orders of magnitude. We cannot use a thick target, because of conversion to e+e- after scattering. Compton scattered electrons, 350 times as frequent as proton compton scattered photons at 100 GeV, will radiate in a thick target to look like photons from proton compton scattering.

3. Will a double arm system work?

The event rate in a double arm system is some two orders of magnitude less than in a single arm system. A factor of $\times 1/30$ comes from a restriction in azimuth, at least as far as a system of the type used by Kreisler et al. to study n-p scattering at the Bevatron and at the AGS is concerned.[1] This restriction might be lifted if we consider putting the hydrogen target in a large aperture magnet. Then perhaps 1/4 of the azimuth would be accessible without too much gymnastics with the spark chambers. A factor of $\sim \times 1/3$ comes from the restriction to $|t| \gtrsim 0.1$ (GeV/c)^2 in order to measure the recoil energy and angle.

In the ($\gamma p \rightarrow \gamma p$) reaction as compared with the ($np \rightarrow np$) reaction we have the following advantages:

a) We can measure the incident photon flux as a function of energy. Therefore the $d\sigma/dt$ values will be absolute values. The optical theorem point then gives us the slope at small t.

b) Both the incident and scattered photon energies can be measured: The first by tagging, the second by using a shower counter as part of the detection system for the forward photon.

c) The use of a convergent photon beam [see for example my note on $\sigma_{TOT}(\gamma p \rightarrow \text{hadrons})$] gives much better definition of the scattering angle of the photon than possible with a divergent neutron beam.

These must be balanced against the fact that the elastic cross section is a very much smaller fraction of the total cross section.

4. What kind of event rate could we get?

Assume we see 1/4 of the azimuth, and a t-range extending out from $|t| = 0.1$. We see 9% of all elastic events.

$$N_{\text{events}} = A \ \ell n\, K_2/K_1 \cdot 6 \times 10^{23} \cdot \frac{1}{20} \times 10^{-30} \cdot 0.09$$
$$= 2.7 \times 10^{-9}\, A \ \ell n\, K_2/K_1.$$

We can expect to get $\sim 10^7$ electrons per pulse at an energy in the 75 to 100 GeV range, in a 1μ steradian, 1% $\Delta p/p$ beam. The radiator, if we tag, should certainly not be thicker than 0.1 radiation lengths. Therefore we can expect $\sim 10^6$ $\ell n\, K_2/K_1$ photons per pulse from such a beam. This would give 2.4 events per hour, not nearly enough. An order of magnitude more flux can be expected if we go down to around 60 GeV. Alternatively a beam with a much bigger $\Delta p/p$ (say ±5%, with 1% resolution) could be used. The resolution in such a beam is quite well matched to the precision with which we can tag. We might need to do both. At that point we run into genuine accidentals problems.

5. Conclusions.

It does not seem worthwhile to attempt to measure $d\sigma/dt$ at $t = 0$. A single-arm photon spectrometer to measure $d\sigma/dt$ seems out of the question by several orders of magnitude. A double-arm spectrometer might work and permit a measurement at $|t| \gtrsim 0.1\ (\mathrm{GeV}/c)^2$. Combined with the optical theorem point, this would give the slope at small t. An event rate of 2.4 to 24 per hour might be possible. An experiment as difficult as this, with such a meager yield of events, is clearly a "second generation" experiment.

REFERENCE

[1] M. N. Kriesler et al., Phys. Rev. Letters 16, 1217, (1966).

B. G. Gibbard et al., Proc. High Energy Physics Conf., Vienna, 1968, (SLAC PUB 520).